INSTRUCTION BOOK

MODEL 75C

DIRECT CAPACITANCE BRIDGE

SERIAL NO. 412

BOONTON ELECTRONICS CORPORATION

[redacted]

EQUIPMENT INSPECTION TAG

Model 75C Ser. 412

Insp. C. Richards Date

This tag is your assurance that this equipment meets the specifications established by our Engineering Dept. and also exhibits the standards of quality and workmanship which apply to all equipment made by

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Form 174

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Boonton ELECTRONICS Corp.

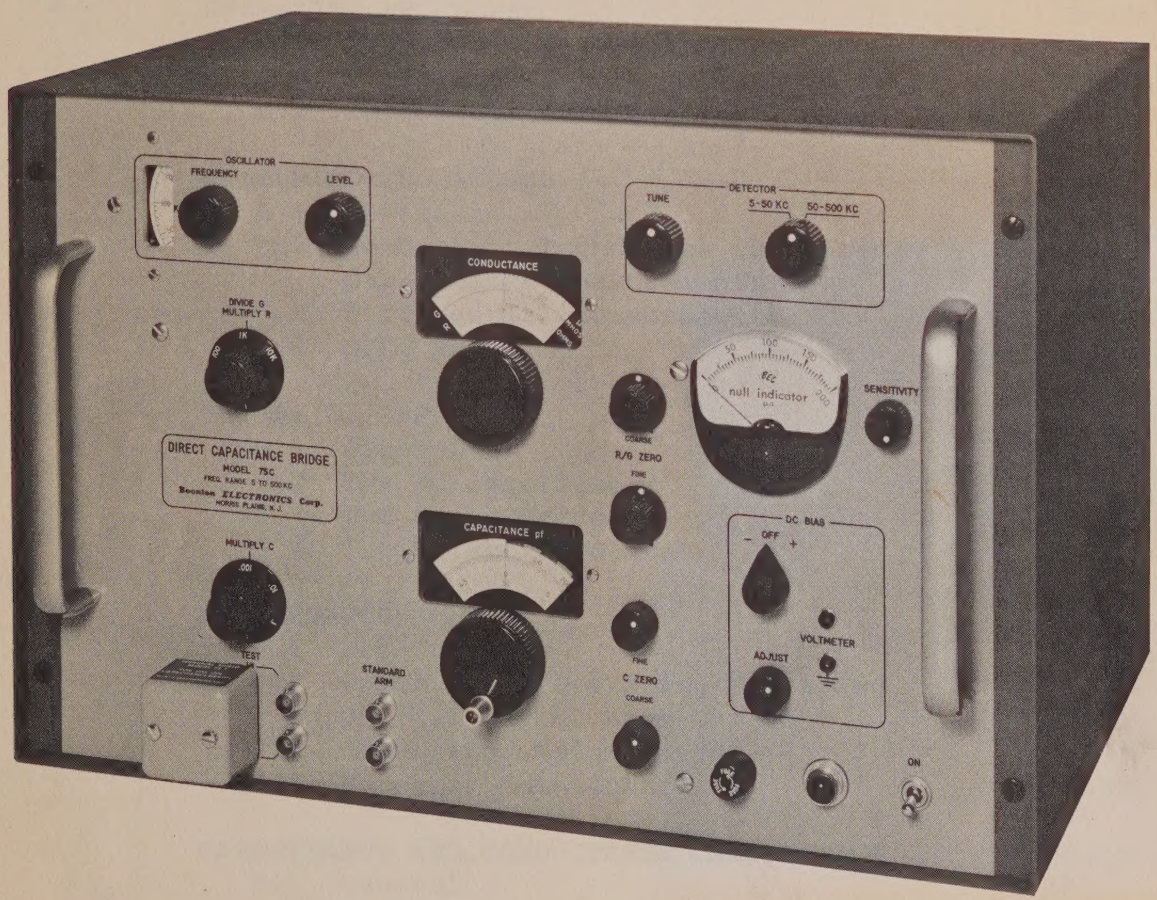
Form 175

INSTRUCTION BOOK

MODEL 75C

DIRECT CAPACITANCE BRIDGE

SERIAL NO. 412



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Boonton *ELECTRONICS* Corporation

738 SPEEDWELL AVENUE, MORRIS PLAINS, NEW JERSEY, U. S. A.

75C INSTRUCTION BOOK

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SECTION 1

MODEL 75C

SPECIFICATIONS

CAPACITANCE: 200 μpf to 1000 pf in 4 decade ranges

Multi-plier	Capacitance Range	Accuracy*
1	100-1000 pf (0.2 pf/div.)	$\pm$ (0.25% + $\frac{1000}{R_p}$ pf + 0.2 pf)
.1	10-100 pf (0.02 pf/div.)	$\pm$ (0.25% + $\frac{1000}{R_p}$ pf + 0.02 pf)
.01	1-10 pf (0.002 pf/div.)	$\pm$ (0.25% + $\frac{1000}{R_p}$ pf + 0.005 pf)
.001	0.05-1 pf 0-0.05 pf (0.0002 pf/div.)	$\pm$ (0.25% + $\frac{1000}{R_p}$ pf + 0.001 pf) $\pm$ (2% + $\frac{1000}{R_p}$ pf + 0.0002 pf)
Where R_p is the equivalent parallel resistance of the test in ohms.		

CONDUCTANCE: 0.001 to 1000 micromhos in 5 decade ranges

Divider	Conductance Range	Accuracy*
1	100 to 1000 μmhos	$\pm(10\% + \frac{Q}{500}\% + 10\ \mu mhos)$
10	10 to 100 μmhos	$\pm(10\% + \frac{Q}{500}\% + 1\ \mu mho)$
100	1 to 10 μmhos	$\pm(10\% + \frac{Q}{500}\% + 0.1\ \mu mho)$
1K	0.1 to 1 μmho	$\pm(10\% + \frac{Q}{500}\% + 0.01\ \mu mho)$
10K	0 to 0.1 μmho	$\pm(10\% + \frac{Q}{500}\% + 0.001\ \mu mho)$

RESISTANCE: 1000 Ω to 1000 megohms in 5 decade ranges

Multiplier	Resistance Range	Accuracy*
1	1K to 10K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^3}\%)$
10	10K to 100K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^4}\%)$
100	100K to 1 megohm	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^5}\%)$
1K	1 megohm to 10 megohms	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^6}\%)$
10K	10 megohms up	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^7}\%)$
Where R is the measured resistance in ohms.		

*These accuracies apply to tests made directly at the HI and LO TEST binding posts or coaxial receptacles. See Section 5 "Measuring Techniques" for limitations applicable to remote measurements.

TEST FREQUENCY:

Continuously variable from 5 to 500 Kc.
Frequency accuracy: ±5%.

SIGNAL LEVEL ACROSS TEST:

Adjustable from below 10 millivolts to approximately 3 volts.

TUBE COMPLEMENT:

1 each 0A2, 6AK5, 6DE7, 6U8, 6X4 and 12AT7.
2 each 6AU6.

POWER REQUIREMENTS:

105 - 125 v, 50 - 60 cps, 55 W.

WEIGHT:

In cabinet 39 lbs.
Rack 32 lbs.

SIZE:

13H x 19-1/2W x 14-7/8D overall in cabinet
12-1/4H x 19W x 12D behind panel when rack mounted.

SECTION 2

GENERAL DESCRIPTION

The Model 75C is a versatile direct-capacitance (three-terminal) bridge with its measuring frequency continuously adjustable from 5 Kc to 500 Kc. The Wien bridge oscillator, multi-stage tuned detector, and power supply are self-contained. No accessories are required for normal use.

It provides essentially the same convenience of operation and general performance characteristics as our fixed frequency models (74C, 75A, and 75B) and permits the investigation of frequency influence on the test.

The signal level across the test is continuously variable from a maximum of about 3 v. to a minimum of less than 10 mv.

Built in provision for applying d.c. bias to the specimen under test is standard.

SECTION 3

DIRECT-CAPACITANCE (THREE-TERMINAL) VS. GROUNDED-CAPACITANCE

3.1 DIRECT-CAPACITANCE

Direct-capacitance is the capacitance existing between two conducting elements, excluding all stray capacitance that may exist to other conducting elements.

Typical examples of direct-capacitance measurements are:

a. Capacitance between the control grid and plate of a pentode vacuum tube, excluding capacitance to cathode, screen grid, or suppressor.

b. Capacitance between any two conductors in a cable, excluding capacitance to all other conductors or the shield.

c. Capacitance between any two conductors of a printed circuit, excluding capacitance to all other conductors.

d. Capacitance between any two windings of a transformer, excluding capacitance to all other windings or shields.

3.2 GROUNDED-CAPACITANCE

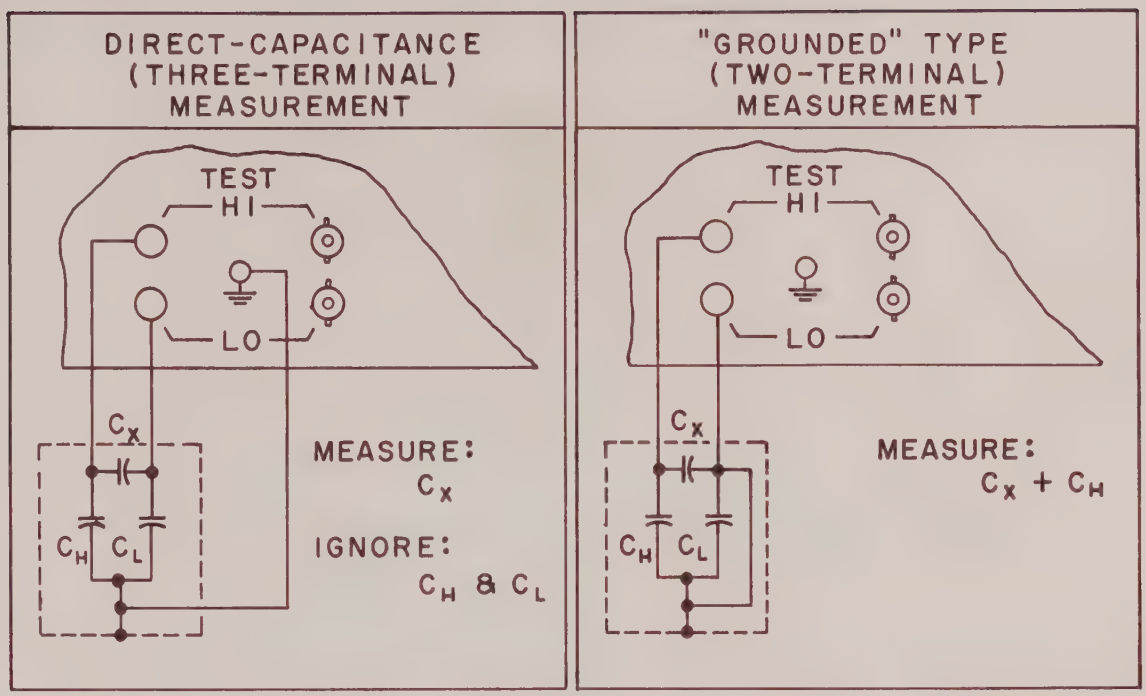
Grounded-capacitance is the capacitance existing between two conducting elements when one element is grounded, and includes all stray capacitance from the high side of the

test to ground, either directly or by way of adjacent elements. For this reason, a grounded-capacitance reading will always be greater than a direct-capacitance reading and will depend upon the proximity of the chassis, adjacent components, and measuring technique.

3.3 CONNECTIONS

For a direct-capacitance (three-terminal) measurement, the two elements between which it is desired to measure capacitance must be connected to the HI and LO TEST binding posts or coaxial receptacles of the bridge. All other elements to which there is capacitance from either of these two elements of interest must be connected to ground (ground binding post or braid of the coaxial cable).

A "grounded type" (two-terminal) measurement may be made on the 75C, provided the test is divorced from true ground and that the LO TEST post is considered to be ground for purposes of the measurement.



Where:

C_X = capacitor to be measured.

C_H = capacitance from HI post side of C_X to shield enclosure of test.

C_L = capacitance from LO post side of C_X to shield enclosure of test.

Note that for a "grounded type" measurement on the 75C the ground post is not used as one terminal of the test, but that the connections normally run to ground for a direct-capacitance measurement are connected to the LO TEST post. For this type of measurement, the allowable stray capacitance from LO TEST post to ground depends on the test frequency and the tolerable error. In general, shunt capacitance up to several hundred pf will result in negligible errors from this source.

SECTION 4

OPERATING PROCEDURE

4.1 SET-UP AND ZERO BALANCING

a. Turn the instrument on and allow a few minutes warm-up.

b. Set to the desired test frequency, using the OSCILLATOR FREQUENCY dial. Turn the OSCILLATOR LEVEL control fully clockwise (maximum output level).

c. Set the conductance range selector switch (marked DIVIDE G/MULTIPLY R) to 1 K.

d. Set the MULTIPLY C switch to the position indicated below:

Range of Capacitance to be Measured	Setting of MULTIPLY C
1000 - 100 pf	1
100 - 10 pf	.1
10 - 1 pf	.01
0 - 1 pf	.001

e. Set the CONDUCTANCE and CAPACITANCE dials to zero (both vernier and counter CAPACITANCE dials at zero).

f. Turn the SENSITIVITY control fully counter-clockwise (minimum sensitivity).

g. If required, connect test leads or fixture as detailed in Section 5 "Measuring Techniques".

h. Adjust the zero balance controls (at the right of CAPACITANCE and CONDUCTANCE dials) for minimum reading on the NULL INDICATOR meter. (The FINE C ZERO and R/G ZERO controls should be set with their dots straight up before adjusting the COARSE controls).

i. Unbalance the bridge by turning the main CAPACITANCE dial for a meter reading of at least 10 μa. Turn the DETECTOR range switch to the appropriate range.

j. Turn DETECTOR TUNE fully counter-clockwise, then slowly clockwise until the maximum meter reading is obtained (note that especially at the lower frequencies there may be secondary peaks at the second and third harmonics).

k. Return the CAPACITANCE dial to zero, turn the SENSITIVITY control fully clockwise (maximum sensitivity), and again balance the bridge using the C ZERO and R/G ZERO controls. At best attainable null there may be a residual reading of about 10 μa on the NULL INDICATOR meter.

l. If reduced test signal levels are required, connect a suitable a.c. VTVM between LO TEST and ground, and set to the desired value using the OSCILLATOR LEVEL control. The normal usable range of adjustment is from

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approximately 3v maximum to 10 mv minimum. Recheck null, and if necessary readjust C ZERO and R/G ZERO controls.

m. If d.c. bias is to be applied to the test a suitable voltmeter may be connected to the VOLTMETER tip jacks, and the polarity and level set with the controls provided. See Section 5.5 for precautions and limitations concerning the d.c. bias system.

4.2 MEASURING

a. Complete the connection to the test, utilizing appropriate techniques as described in Section 5.

b. Adjust the CAPACITANCE and CONDUCTANCE dials for best null indication on the meter. The null should occur between 100 and 1000 on both the CAPACITANCE and CONDUCTANCE dials. If it occurs above or below these values, the next indicated MULTIPLY C and/or DIVIDE G/ MULTIPLY R range should be used.

Note:

Whenever the capacitance or conductance ranges or the test frequency are changed, the bridge should be zero balanced and tuned as previously detailed before measuring.

c. The SENSITIVITY control should be set to give the desired resolution. If set too high, there will be unnecessary difficulty in nulling; if too low, the

resolution and measuring accuracy will be reduced.

4.3 INTERPRETING READINGS

a. Capacitance

After balancing both capacitance and conductance to a satisfactory degree of precision, the capacitance of the test specimen is found by multiplying the CAPACITANCE dial reading by the decimal factor indicated on the MULTIPLY C knob.

b. Conductance

The conductance of the test specimen is found by dividing the reading indicated on the G scale of the conductance dial by the factor indicated on the DIVIDE G/MULTIPLY R dial.*

*For information on errors resulting from remote testing see Appendixes A, B, and C.

c. Resistance

The equivalent shunt resistance is determined by multiplying the reading indicated on the R scale by the factor shown on the DIVIDE G/MULTIPLY R dial.

d. The Q and Dissipation Factor, D, of the test sample may be computed from the following formulae:

$$Q = \frac{2\pi fC}{G} \qquad D = \frac{1}{Q}$$

Therefore at 500 Kc: $Q = 3.14 \frac{C}{G}$

at 5 Kc: $Q = 0.0314 \frac{C}{G}$

Where C = test specimen capacitance in pf.

" G = test specimen conductance in micromhos.

" f = frequency in megacycles.

SECTION 5

MEASURING TECHNIQUES
(See also Appendixes A, B and C)

5.1 GENERAL

When using test frequencies above 100 Kc the effect of added lead length between the bridge and the test specimen cannot always be neglected. With large capacitance tests, the resulting error is primarily due to the lead inductance and resistance.

For capacitance values above about 50 pf, increased lead length produces higher readings of both capacitance and conductance. Each foot of extension of the two leads increases the readings approximately as given in Table I.

TABLE I

Approximate Increase in Reading for 1 ft. Extension of Test Leads (Using RG-58/U Coaxial Cables Only)

C to be Measured	Δ C (pf)			Δ G (μmho)		
	@ 500 Kc	@ 250 Kc	@ 100 Kc	@ 500 Kc	@ 250 Kc	@ 100 Kc
1000 pf	+2.2 pf	+0.6	+0.11	+0.85 μmho	+0.16	+0.015
900 pf	+1.75	+0.44	-	+0.68	+0.13	-
800 pf	+1.4	+0.33	-	+0.56	+0.10	-
700 pf	+1.1	+0.28	-	+0.45	+0.08	-
600 pf	+0.8	+0.2	-	+0.28	+0.06	-
500 pf	+0.55	+0.13	-	+0.2	+0.04	-
400 pf	+0.38	+0.1	-	+0.14	+0.03	-
300 pf	+0.25	-	-	+0.09	+0.015	-
200 pf	+0.1	-	-	+0.04	+0.01	-
100 pf	-	-	-	+0.015	-	-

(See also Graph 1 "Remote Measurement Error Due to Cable Inductance" in Appendix A)

Below about 50 pf the error due to lead inductance becomes less important than that caused by the effects of stray capacitances in the test or the connecting cables. If the test is a pure two terminal capacitor (without shunt capacitances from either terminal to ground), the error introduced by measuring on coaxial cables is small (see Graph 2 "Remote Measurement Error Due to Cable Capacitance" in Appendix A).

If the test has appreciable capacitance between one of its terminals and ground, that terminal should be connected to the LO TEST receptacle on the bridge. This greatly minimizes errors when measuring fractional pf capacitors. Curve (A) (stray C on LO) and Curve (B) (stray C on HI) of Graph 3 in Appendix A illustrate the importance of this for measurements on a 2.2 pf ceramic capacitor.

The errors resulting from measuring a test having appreciable stray capacitance between <u>both</u> its terminals and ground can become quite large. Curve (C) of Graph 3 shows this error for a 2.2 pf test.

Contact fixtures may be used for production testing provided their residual capacitance does not exceed the range of the COARSE and FINE controls (approx. 10 pf).

5.2 CONNECTION TECHNIQUES FOR DIRECT-CAPACITANCE MEASUREMENTS

1. Measurements at the Bridge

If measurements are to be made at the HI and LO TEST binding posts, the test specimen should be connected as close as possible to these posts. All other conductors in the immediate vicinity of the elements under test must be connected to ground using the GND binding post on the front panel.

In many cases it may be more convenient to insert the wire leads of the test specimen directly into the center conductor receptacle of the HI and LO coaxial TEST jacks. This is particularly useful with smaller mica, ceramic, or voltage variable types of capacitors and has the advantage that the outer shell of each jack shields the leads from each other for much of their length.

2. Measurements Using Coaxial Cables

a. With Fixture or Jig

If a fixture or jig is to be used, connect both coaxial leads between it and the bridge before zero balancing.

b. With Shielded Test Equipped with Coaxial Receptacles

When the test is in a metal shield can equipped with coaxial receptacles for connection (as in the

BEC CS-____ Direct-Capacitance Standards), connect both coaxial cables to the bridge and the LO one to the test before zero balancing.

c. Open Test Without Shield or Fixture

Connect both coaxial cables to the bridge, strap or solder their braids together at the test end, and connect the LO center conductor to the test before zero balancing. (The center conductor of the HI cable should be kept away from the test).

5.3 DIFFERENTIAL MEASUREMENTS

GENERAL

In addition to the TEST connections on the front panel, BNC receptacles marked STANDARD ARM have been provided for access to the arm of the bridge opposite that to which a test specimen is connected.

For either differential or temperature coefficient measurements the reference capacitor is connected to the STANDARD ARM via the BNC receptacles, and the test specimen to the TEST BNC receptacles. It is desirable to keep the connecting coaxial cables as short as convenient and of equal lengths to both capacitors.

If the reference capacitor is adjusted at the start of the test to equal the one being tested, the bridge can

then be set to a capacitance range that will give the desired resolution. For example, if a 100 pf ceramic capacitor with a negative T.C. of 300 p.p.m./°C is to be tested to verify its T.C., a set-up can be made with an adjustable air trimmer connected to the STANDARD ARM cables, and the ceramic capacitor connected to the TEST cables. The ceramic capacitor may be in a temperature chamber while the air trimmer is kept at a fixed temperature.

The capacitance of the air trimmer can now be set to equal that of the ceramic, and the bridge switched to the X.01 or X.001 capacitance ranges depending on the desired range of capacitance change to be observed. If the X.001 range is selected and the T.C. is nominal, a 30°C change of capacitor temperature should result in a 1 pf capacitance change (full scale deflection). Had the X.01 range been selected, coverage would have been 1/10 of full scale.

With the connections previously described, the bridge reading will be direct sensing; that is, an upscale reading indicates an increase of capacitance of the test specimen.

When testing capacitors of 10 pf or less for T.C., an external capacitor on the STANDARD ARM is unnecessary since the C ZERO COARSE and FINE controls can be used for

that purpose.

It is best to leave the power on continuously when the greatest possible stability is required for critical T.C. measurements.

CRITICAL MEASUREMENTS

For critical differential measurements when the desired information is the exact difference between an unknown and a reference or standard capacitor, the following measuring technique is suggested:

1. Set-up

Connect the reference to the STANDARD ARM receptacles and the test to the TEST receptacles (using equal length coaxial cables). Follow the general procedure given in SECTION 4 "OPERATING PROCEDURE, SET UP AND ZERO BALANCING", except that the MULTIPLY C and DIVIDE G/MULTIPLY R ranges should be selected for best coverage of the differences to be measured. It may be helpful to balance with the main CAPACITANCE dial at mid-scale or some point other than zero, so that either increase or decrease of capacitance can be measured on-scale. The COARSE and FINE controls have a combined upscale control range of about 10 pf, thus allowing full-scale shift of zero balance on the

X.001 MULTIPLY C range, and full or nearly full scale on the X.01 range.

2. Measuring

Connect the HI coaxial leads to the two capacitors and null the bridge with the CAPACITANCE and CONDUCTANCE dials. Record the readings. Interchange the two capacitors, and again null and record readings.

3. Interpreting Readings

Ideally the two capacitance readings would be in opposite directions from the set-up point, and by equal amounts. Due to minor lead unbalances, however, the usual result will be two readings that are not symmetrically offset from the set-up point, and which may both be in the same direction from it. If desired, the readings may be made more nearly symmetrical about the set-up point by making the LO STANDARD ARM coaxial cable about 7 inches shorter than that used for LO TEST. In any case, one half of the difference between readings is the amount by which the two capacitors differ. Also the difference readings are always direct sensing in that the connection giving the higher reading is the one where the capacitor connected to the TEST receptacles is larger than that on the STANDARD ARM receptacles.

It is worthwhile noting that one of the main advantages of using this method of measuring capacitance differences is that the effects of zero shift in the bridge are eliminated.

As a word of caution, this method is most useful for determining very small differences (such as T.C. effects) between rather large capacitors - roughly between 10 and 1000 pf. It can give serious errors when very large and unequal stray capacitances exist from either side of the test or reference capacitor to ground.

5.4 D.C. BIAS

The d.c. bias voltage that can be applied to the test varies with the resistance of the test; the DIVIDE G/ MULTIPLY R range used; and with the setting of the CONDUCTANCE dial.

Positive bias is derived from +150 v (regulated by a VR tube) and is current limited to approximately 10 ma. maximum by the use of a 15 K ohm resistor in series with the ADJUST control.

Negative bias is obtained from the drop across an avalanche (Zener) diode in series with the negative return of the power supply. Maximum current is approximately 30 ma.

The approximate maximum d.c. voltages across the test under various measurement conditions are given below:

APPROXIMATE MAX. POSITIVE (+) BIAS ON TEST*				
R/G	PARALLEL RESISTANCE OF TEST (Ω)			
RANGE	1 Meg	100 K	10 K	1 K
10 K	107 v.	97 v.	50 v.	8.6 v.
1 K	105 v.	95 v.	49 v.	8.6 v.
100	87 v.	80 v.	46 v.	8.5 v.
10	32 v.	31 v.	28 v.	7.3 v.
1	4.6 v.	4.5 v.	4.4 v.	3.1 v.

APPROXIMATE MAX. NEGATIVE (-) BIAS ON TEST*				
R/G	PARALLEL RESISTANCE OF TEST (Ω)			
RANGE	1 Meg	100 K	10 K	1 K
10 K	5.7 v.	5.7 v.	5.55 v.	4.55 v.
1 K	5.7 v.	5.7 v.	5.55 v.	4.55 v.
100	5.67 v.	5.65 v.	5.53 v.	4.52 v.
10	5.4 v.	5.4 v.	5.26 v.	4.38 v.
1	3.8 v.	3.8 v.	3.7 v.	3.25 v.

*CAUTION

1. Turning the CONDUCTANCE dial through the uncalibrated area will produce an abrupt rise of bias voltage when the rotation causes the arm to open-circuit.

2. The bias actually present across the HI and LO TEST posts will be less than that measured at the VOLTMETER tip jacks due to the resistance of the bridge output choke. In general the error from this source is unimportant except on the X1 R/G range, where it reaches a maximum of 30% at 1000 ohms.

SECTION 6

THEORY OF OPERATION

6.1 GENERAL

The output signal of an RC oscillator is fed to a modified Young bridge. The bridge output, first amplified by a high-gain frequency selective amplifier, is then rectified and used to actuate the NULL INDICATOR meter.

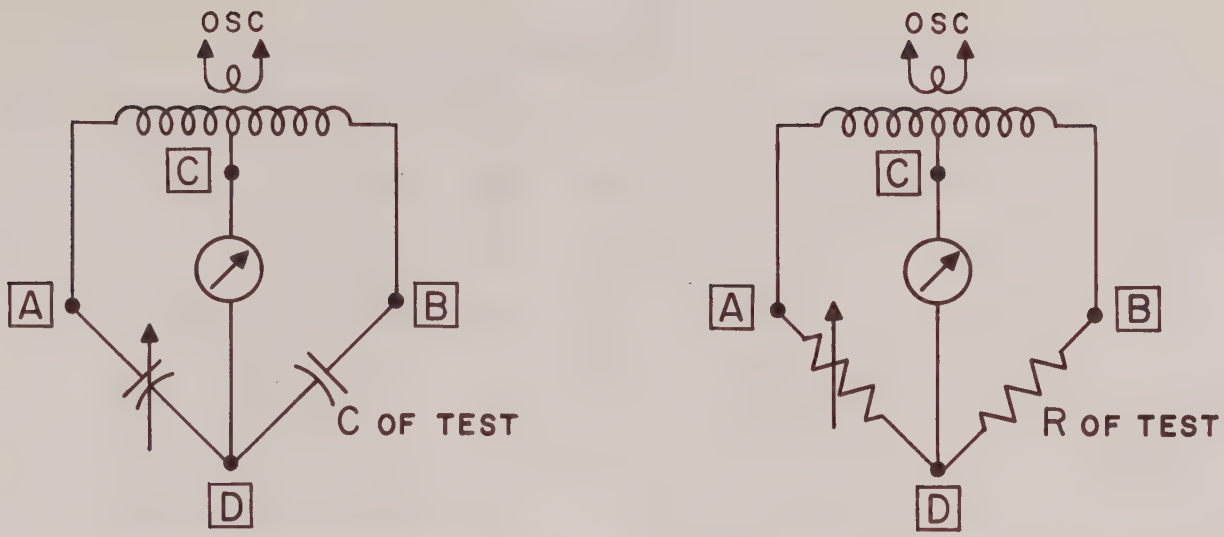
6.2 THE RC OSCILLATOR

The resistance tuned Wien bridge RC oscillator uses a thermistor to control the negative feedback, thus simplifying tube requirements and allowing use of a single twin triode (12AT7) in the oscillator. The entire frequency span from 5 to 500 Kc is covered in one continuous dial range.

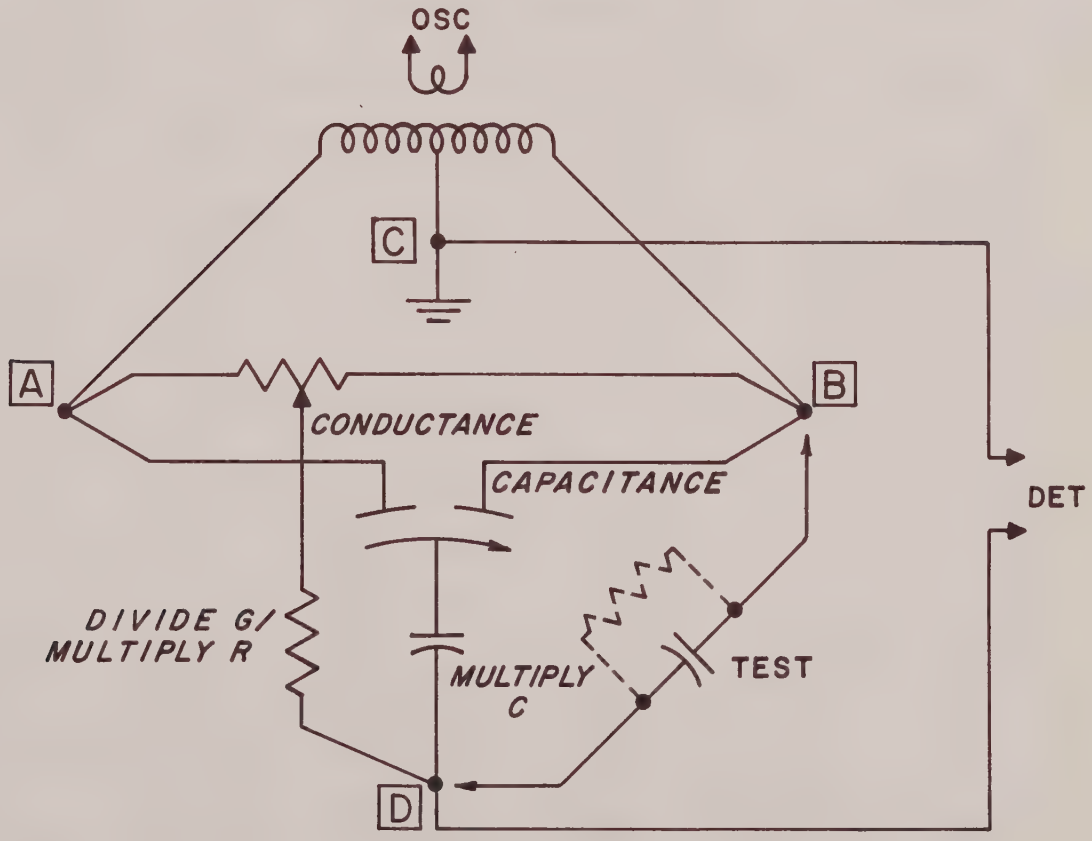
A two stage twin triode (6DE7) amplifier follows the oscillator. The input section serves as a buffer feeding the power output section.

6.3 THE YOUNG BRIDGE

The signal from the oscillator section is coupled to the bridge by a specially designed input transformer that produces two signals exactly equal in amplitude and opposite in phase (A to C and B to C in Figure 1).



BASIC BRIDGE CIRCUITS FOR C AND R



SIMPLIFIED SCHEMATIC OF 75C BRIDGE

75C

Figure 1

The signal appearing at D will thus be zero with respect to C only when arms B to D and A to D are made to contain exactly equal capacitances and resistances.

Separate and non-interacting bridge circuits are provided for the capacitive and resistive elements, and means are included for covering decade ranges and for zero balancing.

6.4 THE DETECTION SYSTEM

The detection system uses five cascaded stages of amplification: a single stage preamplifier, a two-stage tuned amplifier section of unique design, and a two-stage broadband amplifier.

The 6AK5 preamplifier which uses conventional pentode circuitry feeds the first cathode of the 6U8 two-stage tuned amplifier.

This amplifier uses RC coupling, and has both positive and negative feedback loops. The negative feedback is applied to the first stage cathode through a non-frequency-sensitive divider. The positive feedback goes to the first stage grid through the frequency sensitive portion of the resistance tuned Wien bridge.

At the frequency to which the Wien bridge is tuned, the net feedback is made slightly negative, but at the other frequencies the negative feedback predominates. When

properly adjusted, there is approximately 30 db of attenuation one octave away from the selected frequency

Injection of the input signal is made to the cathode rather than the grid of the first stage. This gives favorable loading of the preamplifier and avoids the usual isolation requirements encountered when grid injection is used.

A two-stage broadband amplifier follows the frequency sensitive section. The amplified signal is rectified and used to actuate the NULL INDICATOR meter, and also provides an AGC voltage that helps keep the meter reading on scale when the bridge is off null.

SECTION 7

MAINTENANCE

7.1 GENERAL

No preventative maintenance is required or recommended. Tubes should not be replaced unless they fail to perform satisfactorily. No selection is necessary, although some readjustment may be required when the following tubes are replaced:

V1 (12AT7) Oscillator (see 7.4).

V4 (6U8) Tuned Amplifier (see 7.5).

A suggested sequence to follow when trouble is suspected is first to perform the "Quick-Check" series (see 7.3) to get an idea of the general mechanical and electrical operation.

If resolution is found to be sub-normal, the overall functioning of the oscillator section may be determined by connecting a wideband oscilloscope to the LO TEST receptacle (OSCILLATOR LEVEL set fully clockwise). Distortion should be barely visible (5 to 7% at 5 Kc), and the level should be about 2.5 to 3 v from 5 to 500 Kc.

Assuming the TEST signal is found normal, the detector operation can be given a rough check by observing that there is no oscillation in the tuned amplifier (this

shows up as an abrupt jump to full scale meter reading at some point or points in the range of the DETECTOR TUNE control), that the AGC action is smooth and gives a usable indication of the necessary dial rotation direction for null, and that peaking is possible at any frequency from 5 to 500 Kc. See 7.5 for further information on the tuned amplifier.

Component failure can sometimes be located by voltage measurements. See 7.2 for a chart of expected voltages under specific conditions.

D.c. bias should be approximately as detailed in 5.5.

See Section 8 for information on the subject of calibration.

7.2 NORMAL D.C. OPERATING VOLTAGES

CONDITIONS:

1. Coaxial connectors P1, P2, and P4 disconnected from J1, J2, and J4.
2. OSCILLATOR LEVEL and SENSITIVITY controls fully clockwise.
3. Line input 117 v. 60 ∿.
4. Readings taken with d.c. voltmeter with 10 megohm input resistance.

Note:

Voltages given are approximate. Variations of up to 10% or more can be expected in some instances.

Tube	Pin Number								
	1	2	3	4	5	6	7	8	9
V1 12AT7	109		2.7			174		1.5	
V2 6DE7	143					195		7.2	17
V3 6AK5					107	40	1.0	-	-
V4 6U8	134		104			76	.95	5.4	
V5 6AU6					77	77	1.0	-	-
V6 6AU6					224	160	2.4	-	-
V7 6X4							356	-	-
V8 0A2	148							-	-

7.3 OVERALL PERFORMANCE CHECKOUT

1. "Quick-Check" Series

This series of checks, requiring no auxiliary equipment, can detect several forms of mechanical and electrical mal-functioning.

A bridge that passes the "Quick-Checks" is not guaranteed to be normal, but a normal bridge should pass without difficulty.

a. Dial Stop (Mechanical Check)

(Checks the dial stop action and correctness of dial alignment with variable capacitor rotary position.) Rotate the CAPACITANCE dial until the stop is reached (at -50). The fiducial should be over the mark on the counter (outer) dial, and should

coincide with 0 on the inner dial (within ± 2 small divisions).

b. Capacitance Zero (Electrical Check)

(Checks the setting of internal zero adjustments and general balancing of capacitance circuits at zero). Turn on and allow 5 minutes warmup. Switch DIVIDE G/MULTIPLY R to 1K and MULTIPLY C to X1. Turn the OSCILLATOR LEVEL and SENSITIVITY controls full on. Set the CAPACITANCE and CONDUCTANCE dials at zero.

Turn OSCILLATOR FREQUENCY to 100 Kc. Switch the DETECTOR to the 50-500 Kc range, turn DETECTOR TUNE fully counter-clockwise, then slowly clockwise for a peak reading.

Balance the bridge with the C ZERO and R/G ZERO controls. Balance should be obtained with the COARSE C ZERO white dot near the top (near mid-rotation), and must not be near either electrical maximum or minimum.

Rotate the CAPACITANCE dial all the way to the upper stop, observing that the meter indication rises and that there are no nulls at any points other than zero. The upper stop should act at approximately

1050 (within ± 5) dial pf.

c. CAPACITANCE Dial Backlash

(Checks for normal operation of the entire variable capacitor system, including the v.c. and its gearing and drive mechanisms.)

Set up as for b and balance the bridge. When the CAPACITANCE dial is turned from at least 10 dial pf off null into the null, the null should occur at the same dial point whether approached from a clockwise or counter-clockwise direction. If it differs by more than 1 small division, the backlash is excessive (it is still usable, however, if the same null point is always obtained when approached from the same direction).

d. Capacitance Sensitivity (Resolution)

(Checks for proper oscillator and detector functioning and gives a useful measure of resolution.)

Set up as for b, except use the X.001 MULTIPLY C range. With SENSITIVITY full on, balance for the lowest possible NULL INDICATOR meter reading. When the CAPACITANCE dial is turned 1 dial pf in either direction from null, the increase in meter reading should be at least 20 μa.

e. Oscillator/Detector Check

(Gives a rough indication of correctness of alignment, and of general functioning.)

Set up with SENSITIVITY fully clockwise, MULTIPLY C on X1, R/G on X 1K, OSCILLATOR FREQUENCY at 5 Kc and DETECTOR RANGE on 5-50 Kc. Turn DETECTOR TUNE fully counter-clockwise, then slowly clockwise for peak (maximum meter reading). Balance the bridge. Mis-set the CAPACITANCE dial for a meter reading of 150 μa.

Next set the OSCILLATOR FREQUENCY dial at 50 Kc and re-peak with DETECTOR TUNE. The meter reading should be at least 125 μa.

Switch to the 50-500 Kc detector range. Turn DETECTOR TUNE fully counter-clockwise, then slowly clockwise for peak. Again, meter reading should be at least 125 μa.

Finally, set the OSCILLATOR FREQUENCY to 500 Kc and peak with DETECTOR TUNE. Meter reading should be at least 125 μa.

f. Conductance Zeros

(Checks for proper relation between the dial zero and the electrical network and can detect some

types of bridge input transformer mal-function.)

Switch DIVIDE G/MULTIPLY R to 1, MULTIPLY C to 1. Turn both R/G ZERO controls with white dot up. Turn the CAPACITANCE dial to 0. Balance the bridge, using the CONDUCTANCE dial and COARSE and FINE C ZERO controls. Balance should occur within one small division of 0 on the CONDUCTANCE dial.

Leave the CONDUCTANCE dial at the above setting. Switch to each of the DIVIDE G/MULTIPLY R ranges and determine that the bridge can be balanced with relatively little offset of the R/G ZERO controls (within about ± 1 hour of the initial 12 o'clock setting).

7.4 OSCILLATOR MAINTENANCE

When V1 (12AT7) is replaced, the operating frequency may not track the OSCILLATOR dial calibration at the high frequency end. To restore tracking connect a counter to the LO TEST receptacle, remove the shield cover of the oscillator-detector chassis, and adjust control (K) (C6) so that 500 Kc coincides with the 500 Kc dial calibration.

Normally, no other oscillator maintenance is required, but in rare instances the oscillator may fail to stabilize within the usual period of less than one minute. The probable

cause of this is deterioration of the thermistor (TH-1), and its replacement will restore normal functioning.

Factory adjustment (H) (C3) sets the low frequency end of the range. It normally need not be reset.

Similarly, factory adjustment (L) (R9) has been pre-set so that with the OSCILLATOR LEVEL control set fully clockwise the test signal level (at the LO TEST receptacle) is 3 v at 100 Kc. Re-setting usually is not required unless a replacement V2(6DE7) tube differs greatly from the one with which it was originally adjusted.

7.5 DETECTOR MAINTENANCE

A. General

Replacement of V4(6U8) may require some re-adjustment, although if several 6U8's are available one can usually be found that will give satisfactory results without it.

Replacement of the dual DETECTOR TUNE potentiometer may or may not result in a need for re-adjustment. This is factory pre-tested for tracking of the two elements, using a sensitive differential checkout procedure. A possible reason for replacement would be the development of local open

circuiting of the rotor contact(s), which would result in oscillation at specific rotation points.

After set-up at the factory, the final position of each control was indicated by a color mark. Unless a control has been replaced, the color mark should be used as the starting point for re-adjustment.

The following detailed procedure gives all steps necessary to adjust a new unit completely.

B. Adjustment of Tuned Amplifier

1. Equipment Required:

a. Oscillator that covers frequency range of 5 to 500 Kc (one with built-in attenuator and constant output voltage over the frequency range is preferable.)

(H.P. 200 CD with separate attenuator to reduce signal level to 1 mv or less, or equivalent.)

b. Ac VTVM with flat response between 5 and 500 Kc, with db scale, and with measurement capability from 1 v to less than 10 mv. Should have a low capacitance probe.

(Ballantine 314 or equivalent)

c. Oscilloscope with low capacitance probe (Telequipment Serviscope Type S-32 or equivalent)

d. Insulated screwdriver.

2. Setup

a. Remove V2(6DE7) and V5(6AU6) tubes from their sockets. Disconnect the coaxial cable from the preamplifier input (at J2).

b. Connect the output of the H.P. 200 CD (with attenuator) to the preamplifier input jack, J2. Adjust the signal level at J2 to about 1 mv (use the Ballantine 314).

c. Connect the Ballantine 314 and Telequipment S32 probes in parallel to the output jack of the Tuned Amplifier (use TEE connector on J3 so that the Wideband Amplifier can be left connected).

d. Remove the shield covering controls (A) through (G) and check that all color markings coincide.* Replace the shield.

* To pre-set replacement controls proceed as follows:

a. "Dime pots"

Using the screwdriver slot, turn the rotor fully counterclockwise. When so set, and when viewed with the solder lugs at top, the slot will point at about 4:30 and 10:30 o'clock. Use the 4:30 end as the reference when pre-setting to the following suggested starting points:

Control →	(A)	(B)	(C)
Pre-set to →	8:30	8:00	8:00

b. Ceramic Variable Capacitors

Turn the rotor so that the silvered half is toward the mounting holes (max. C). At this point the slot will be roughly vertical when viewed with the mounting screws towards you. Use the 6 o'clock end as the reference when pre-setting to the following suggested starting points:

Control →	(D)	(E)	(F)	(G)
Pre-set to →	11:00	3:30	3:00	4:30

3. Adjustment Procedure

a. Turn the 75C on. Allow a five minute warm-up.

b. Set the DETECTOR range switch to 5 - 50 Kc, turn SENSITIVITY fully clockwise, DETECTOR TUNE fully counter-clockwise, and set the H.P. 200CD to 5 Kc.

c. Turn the DETECTOR TUNE control slowly clockwise and tune for maximum reading on the Ballantine 314. The reading should be around 0.8 v. If not, set for 0.8 v using the AMPLITUDE control of the H.P. 200CD.

d. Without disturbing the setting of DETECTOR TUNE,

set the H.P. 200CD to 10 Kc (the second harmonic of 5 Kc). The reading on the Ballantine 314 should be about 30 db below that obtained with 5 Kc input (approximately 0.025 v). If necessary, set control (D) until the desired 30 db is achieved.

e. Set the H.P. 200CD at 50 Kc and carefully peak DETECTOR TUNE. If it peaks at about the same 0.8 v meter reading, check the 100 Kc second harmonic. The reading should be about 30 db below that for 50 Kc. If it is, proceed with step f; if not, and if there is either oscillation on less than the desired 30 db of discrimination against the 100 Kc second harmonic, adjust control (A) . When stable operation and about 30 db of discrimination are achieved at both 5 and 50 Kc proceed with step f.

f. The tuning range of DETECTOR TUNE (on the 5 - 50 Kc band) should now be checked using the H.P. 200CD. Minimum and maximum frequencies should preferably be about 4.5 Kc and 65 Kc, but not more than 4.9 Kc or less than 55 Kc.

g. Check operation over the entire 5 - 50 Kc band, with suggested check points being 5, 10, 20, 30, 40 and 50 Kc. Discrimination should preferably be between 28 and 31 db at all points. Much more

75C
a

than 31 db is to be avoided for stability reasons, while much less than 28 db does not provide the desired harmonic rejection.

h. Switch to the 50 - 500 Kc band. Set control (F) so that 50 Kc on this band falls at about the same DETECTOR TUNE knob setting as 5 Kc on the low band. Check discrimination, and if necessary set control (E) to produce the desired 30 db of discrimination. Re-check the knob setting for 50 Kc (controlled by (F)). Repeat (F) and (E) settings until both frequency and discrimination are as specified.

i. Check at 180 Kc. If necessary, set control (B) .

j. Recheck discrimination at 50 Kc. When results at both 50 Kc and 180 Kc are correct, check at 500 Kc. Use control (C) if adjustment is necessary.*

k. Again re-check 50 Kc and 180 Kc. Repeat the operation of steps h, i, and j until results are satisfactory at all three frequencies.

l. Check results across the band. Suggested check points are 50, 100, 200, 300, 400, and 500 Kc. Again, as in step g, discrimination

should fall between 28 and 31 db with 29 to

30 db preferred.

* Since the maximum frequency on the H.P. 200CD is 600 Kc, it is necessary to check discrimination at half-frequency when tuning above 300 Kc.

SECTION 8

CAPACITANCE AND CONDUCTANCE CALIBRATION

8.1 GENERAL

This capacitance bridge has been calibrated at the factory by trained specialists using equipment developed especially for the purpose.

Many of the calibration steps must be performed in strict sequence, and use of accurate three-terminal capacitance standards is mandatory.

No re-calibration should be attempted by the customer.

Calibration accuracy is <u>not</u> affected by removing the instrument from the cabinet or by replacing tubes, but the sealed bridge unit must not be opened.

8.2 CHECKING CAPACITANCE CALIBRATION

When calibration must be checked, accurate direct-capacitance standards should be used, and proper technique is essential for accurate results.

Before checking, the bridge should be allowed to reach thermal stability (8 hour warm-up), and the standards should be at room temperature (preferably 25°C).

At frequencies above 100 Kc, and when checking the calibration of the X1 CAPACITANCE range, the shortest practical coaxial cables should be used for connecting the standards to the bridge to avoid errors resulting from the effects of their inductance. (See Appendix B for a discussion of this problem).

When connecting the standard, both cables should be connected to the bridge and the LO cable to the standard, before zero balancing the bridge. The HI cable should then be connected to the standard and the measurement made.

8.3 CHECKING CONDUCTANCE CALIBRATION

To check the operation of the conductance measuring circuits, first set the DIVIDE G/MULTIPLY R and the MULTIPLY C switches at 1 and the CAPACITANCE dial at zero. The R/G ZERO control should be set near mid-rotation (with the pointer up).

Next, balance the bridge using the COARSE and FINE capacitance controls, and the main CONDUCTANCE dial. Balance should be reached with the CONDUCTANCE dial at or near zero (within ONE DIAL DIVISION, i.e. $\pm$10 μmhos).

With the CONDUCTANCE dial left at the setting that yielded balance on the X1 DIVIDE G/MULTIPLY R range, it should be possible to achieve a conductance balance on

all other DIVIDE G/MULTIPLY R ranges using only the R/G ZERO control and the COARSE and FINE capacitance controls. (Do not connect any cables or test fixtures to the bridge while making this test).

A quick test of operation on all DIVIDE G/MULTIPLY R ranges may be performed using 1K, 10K, 100K, and 1 megohm, 1/4 watt, ±1% deposited carbon resistors.

a. First, set up the bridge as detailed in the first two paragraphs. Then insert the wire leads of the 1K resistor into the centers of HI and LO TEST coaxial receptacles and balance the bridge using the CONDUCTANCE and CAPACITANCE dials. Read the indicated value on the CONDUCTANCE dial.

b. Remove the 1K resistor, switch to "10" on the DIVIDE G/MULTIPLY R control, turn the main CAPACITANCE and CONDUCTANCE dials to zero and re-balance using the R/G ZERO controls and the COARSE and FINE capacitance controls. Connect the 10K resistor and again balance using the CONDUCTANCE and CAPACITANCE dials. Read the indicated resistance value on the CONDUCTANCE dial and multiply by 10.

c. Repeat the same procedure on the X100 and X1000 ranges, using the 100K and 1 megohm resistors respectively. In all cases readings should fall within ±11% of full scale on the CONDUCTANCE dial.

SECTION 9

WARRANTY

Boonton ELECTRONICS Corporation guarantees to the original purchaser that each instrument it manufactures will be free from defects in material and workmanship for a period of one year after date of initial shipment. Our liability is limited to repairing or replacing any defective part with the exception of vacuum tubes, panel lamps, fuses, and batteries. The warranty lapses if, upon our examination, we judge that the instrument has been abused in any way.

PROCEDURE TO FOLLOW IF THERE IS DIFFICULTY WITH THE INSTRUMENT

1. Call our plant or our representative nearest you. A simple solution may result from discussion of the problem with our trained personnel.
2. If the fault is not readily eliminated, prepare the instrument for return to us. Pack carefully in a sturdy container using several inches of shock absorbing material on all six sides of the instrument. Include all probes, cables, or accessory units. On all paper work pertaining to the returned instrument, note the model and serial number and state briefly the details of the fault. Ship to us transportation charges prepaid.

3. If the instrument is within the warranty, we will repair and return to you transportation charges prepaid. If the instrument is beyond the one year warranty period, we will repair and return it unless approval of a cost estimate is requested. If the instrument is within the one year warranty period, but our examination reveals abuse, we will await approval of our cost estimate before proceeding with repairs.

SECTION 10

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APPENDIX A

SOME COMPARISONS BETWEEN CAPACITANCE MEASUREMENT ERRORS AT 100 KC AND 1 MC

A. GENERAL

Use of 100 Kc as the test frequency offers considerable advantage in several areas which include:

1. Measurements above 100 pf, whether remotely or at the bridge.

2. Practically all remote measurements when appreciable capacitance exists between either HI or LO TEST post and ground.

3. All measurements when the test itself is not a simple two-terminal capacitor, but has capacitance from either or both terminals of the test to other elements.

Figure A-1 shows the recommended set-up procedure for making remote measurements.

B. ERRORS DUE TO LEAD INDUCTANCE

Above about 100 pf the use of 100 Kc as the test frequency greatly reduces the error due to the inductance of leads connecting the bridge to the test.

Graph 1 shows the added error due to lead inductance when 1 foot long RG-58/U coaxial cables are added between the bridge and the test capacitor. It is apparent that at 100 Kc this error is about 100 times less than at 1 Mc.

It should be noted that Graph 1 does not give total measurement errors - only the increase in reading per foot of the specified coaxial cables. At 1 Mc, the inductance of leads internal to the bridge can and does contribute appreciable error. (See Table on next page for average errors in the 75A at 1 Mc due to internal inductance).

This error, of course, is present whether open wire leads or coaxial cable are used to connect the test to the bridge.

C. ERRORS DUE TO COAXIAL CABLE CAPACITANCE

Below about 50 pf the capacitance between the center conductor and outer braid of the coaxial cables causes an increase in capacitance reading. This effect is generally negligible at 100 Kc, but appreciable at 1 Mc. Graph 2 shows the approximate magnitude of this error. Note that the error is not a constant percent-per-foot; instead it becomes greater the longer the cables.

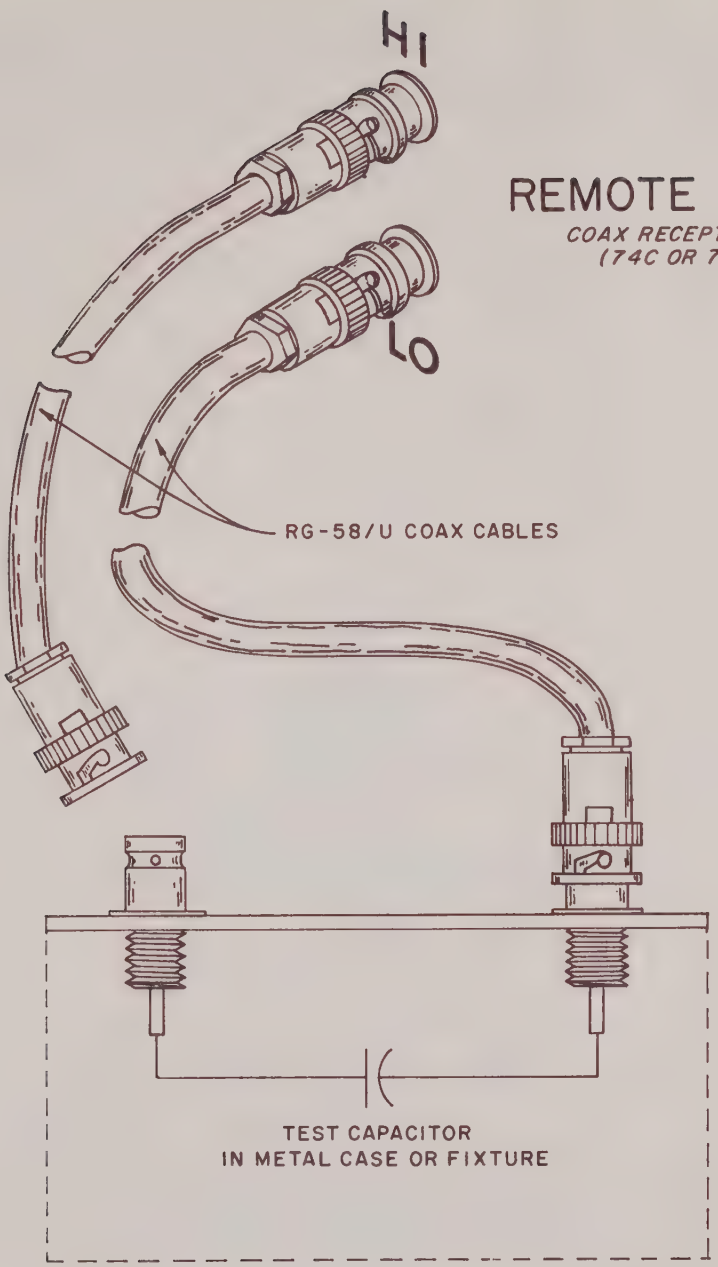
D. ERRORS DUE TO MEASURING OTHER THAN A SIMPLE TWO-TERMINAL TEST

Graph 3 shows representative errors when measuring a 2.2 pf ceramic capacitor in the presence of capacitance between the LO side of the test and ground (cable braid); the HI side and ground; and with equal values from both sides to ground.

75A CAPACITANCE BRIDGE AT 1 MC

CORRECTIONS FOR INTERNAL INDUCTANCE: X1 CAPACITANCE RANGE ONLY

CAPACITANCE DIAL READING (pf)	50	100	200	300	400	500	600	700	800	900	1000
ADJUST READING BY ADDING: (pf)	+.15	+.28	+.42	+.55	+.52	+.41	+.26	0	-.4	-.8	-1.2



SETUP FOR REMOTE MEASUREMENT OF CAPACITORS USING COAXIAL CABLES (DIRECT ONLY)

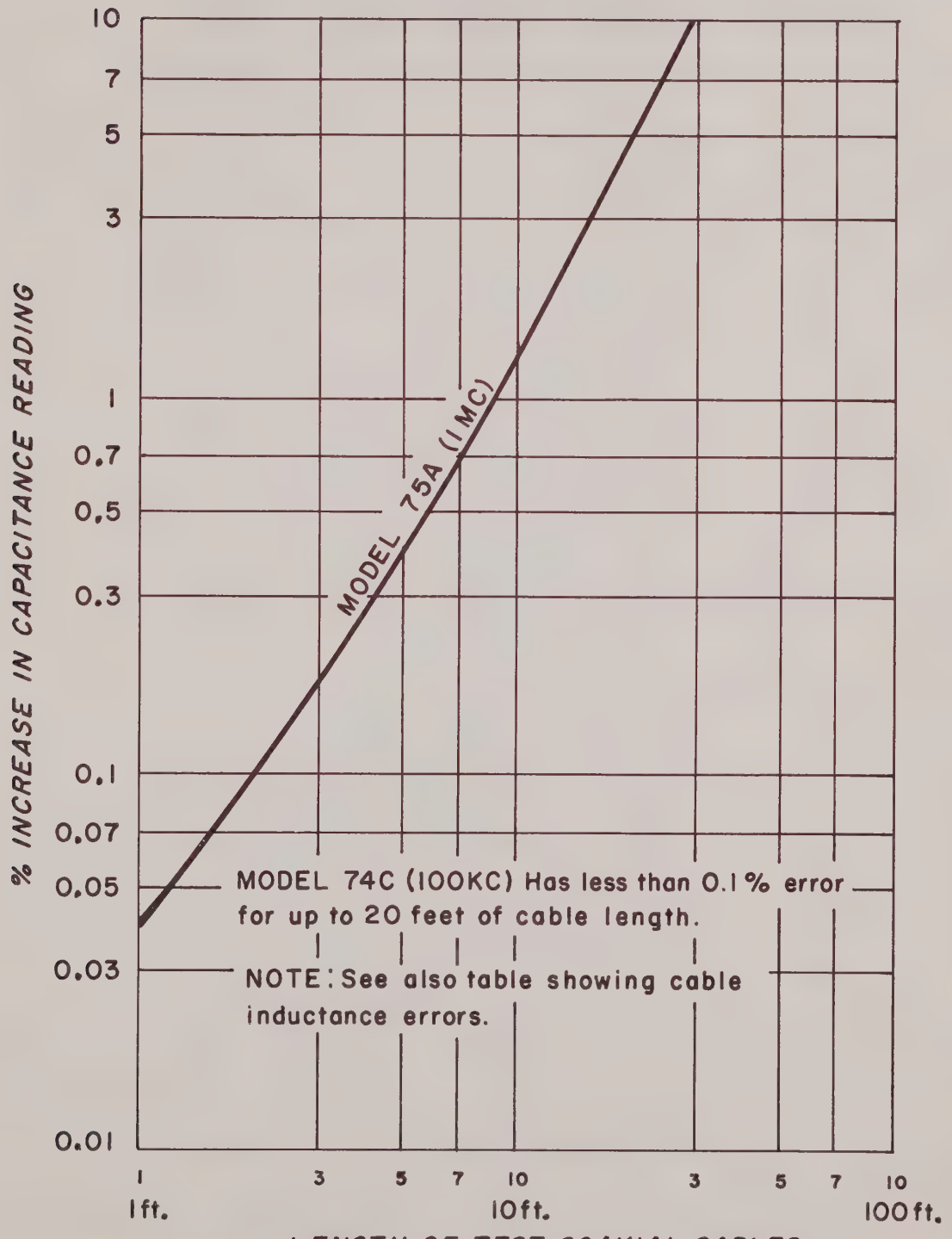
PROCEDURE:

1. *Connect both cables to the bridge, and connect the* LO *cable to the case receptacle of the test that has the greatest capacitance to case (if any).*
2. *Balance the bridge*
3. *Connect the* HI *cable to the other case receptacle and measure.*

Figure A1

(830,070A)

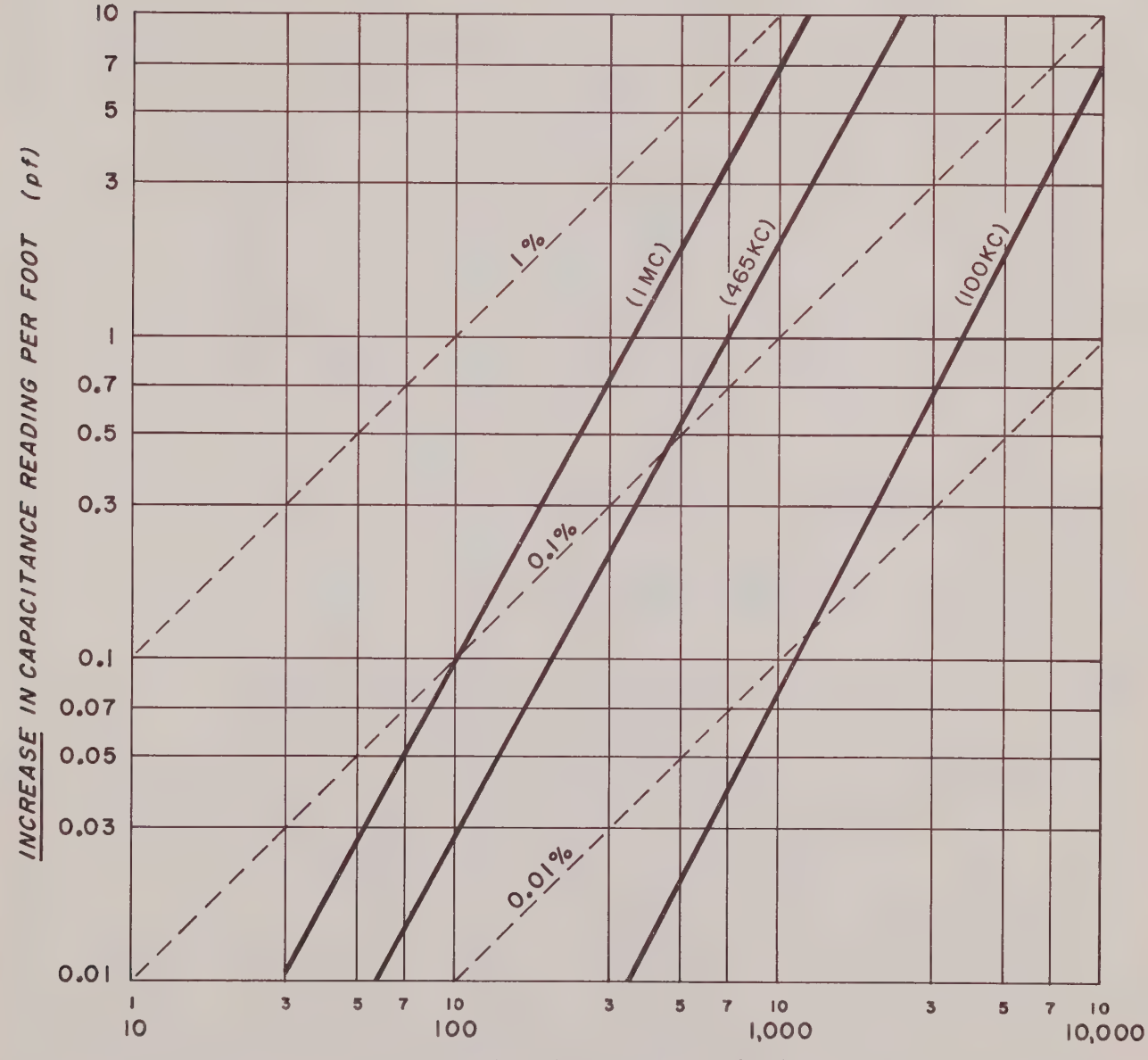
REMOTE MEASUREMENT ERROR DUE TO CABLE CAPACITANCE



Graph 2 (830,068A)

REMOTE MEASUREMENT ERROR DUE TO CABLE INDUCTANCE

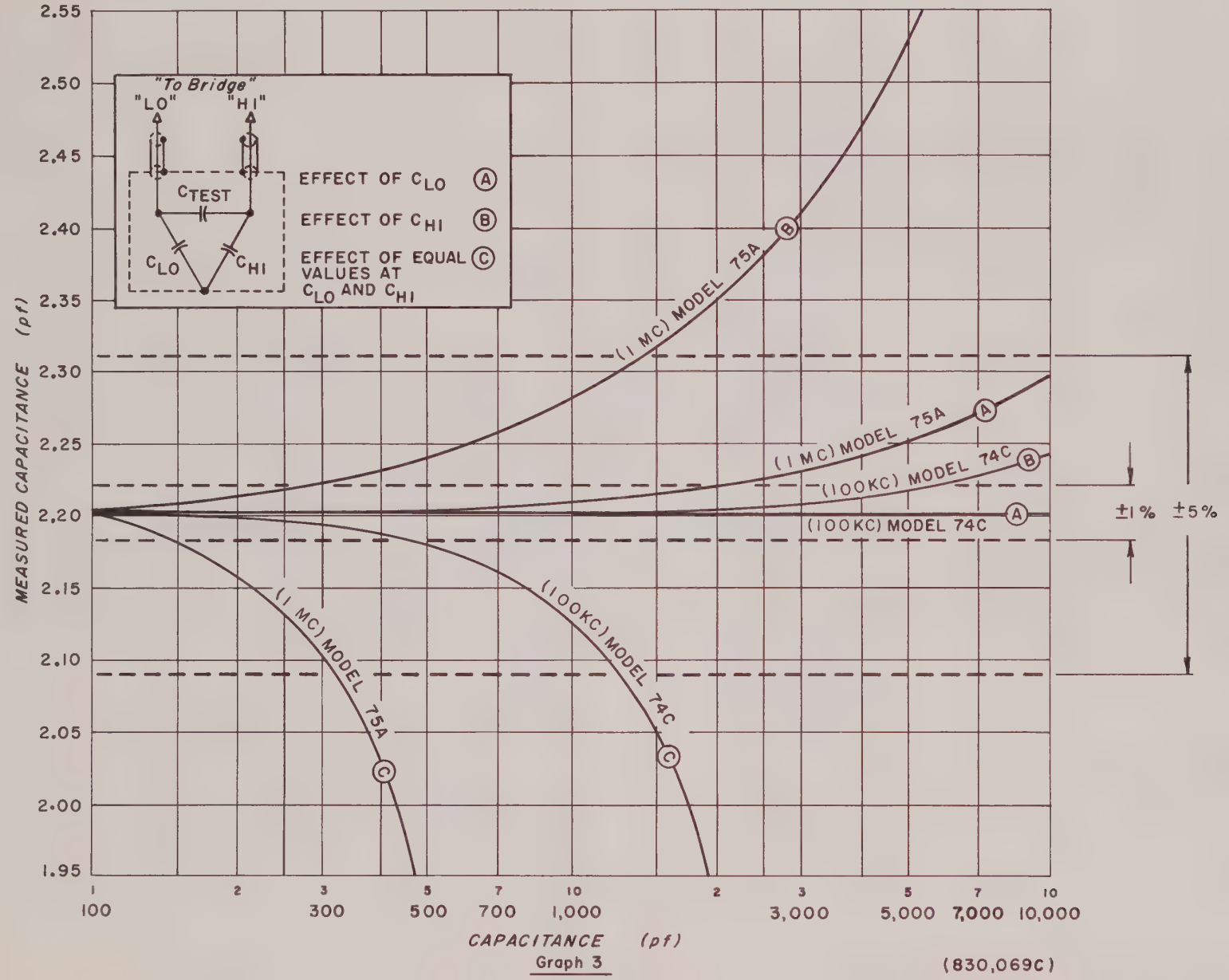
(INCREASE IN CAPACITANCE READING PER FOOT OF RG-58/U CABLES)



Graph 1

(830,067C)

REPRESENTATIVE ERRORS WHEN MEASURING A 3-TERMINAL CAPACITOR



Graph 3

(830,069C)

APPENDIX B

THE USE OF CAPACITANCE STANDARDS LARGER THAN 100 pf FOR CHECKING CAPACITANCE ACCURACY ON THE X1 CAPACITANCE RANGE OF THE 75A AT FREQUENCIES ABOVE 100 KC.

INTRODUCTION

At 1 Mc lead inductance effects become the limiting factor in making accurate capacitance measurements above approximately 100 pf. This paper offers specific suggestions for minimizing errors from this source.

In the design of the 75A great care was taken to minimize internal inductance, with the final design having less than 0.25% error in reading between 100 and 1000 pf without the use of a correction chart, provided the test is connected directly at the HI and LO TEST binding posts or directly at the centers of the TEST coaxial receptacles. The internal inductance errors may be further minimized by applying the corrections given in the Table below.

75A CAPACITANCE BRIDGE AT 1 MC

CORRECTION AT 1 MC FOR INTERNAL INDUCTANCE: X1 CAPACITANCE RANGE ONLY

CAPACITANCE DIAL READING (pf)	50	100	200	300	400	500	600	700	800	900	1000
ADJUST READING BY ADDING: (pf)	+.15	+.28	+.42	+.55	+.52	+.41	+.26	0	-.4	-.8	-1.2

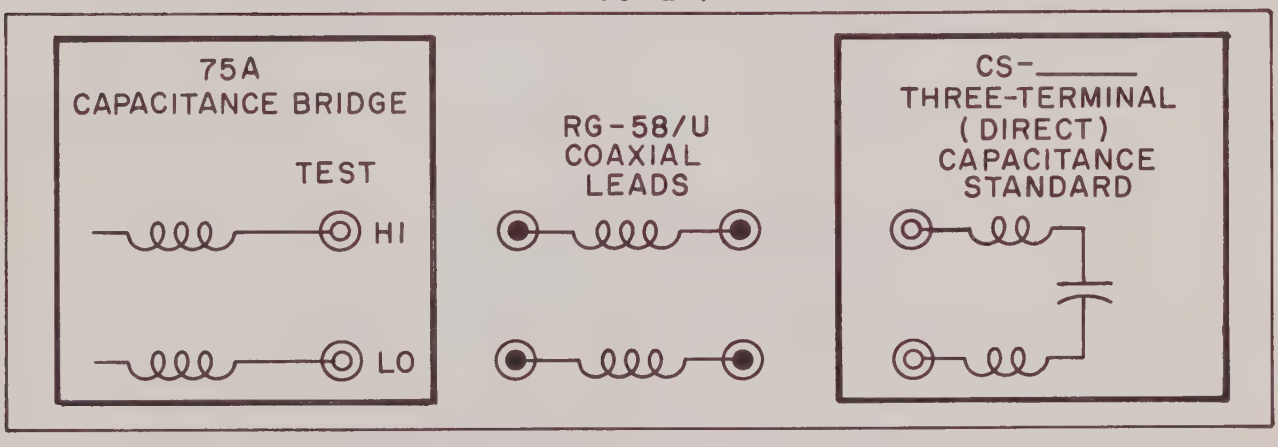
It has been our policy to recommend that our 1 Mc bridges be returned to us for calibration checks, since we have both the trained personnel and the specialized equipment to do an accurate job.

When the customer elects to perform the checking of the bridge calibration, we recommend that the X1 capacitance range

(100 to 1000 pf) be checked initially at 100 Kc, thus eliminating the need to consider the effects of inductance in the bridge, in the coaxial leads, or in the standard.*

If the calibration is found to be within specifications at 100 Kc it may then be checked at 1 Mc, with the knowledge that differences between readings at the two frequencies are directly attributable to the effects of inductance in the bridge, the leads, or the Standards. (See Figure 1)

FIGURE 1



* A suitable 100 Kc unit designated "75-2A 100 Kc Oscillator/ Detector Unit", is available. It is mechanically and electrically interchangeable with its 1 Mc counterpart in the 75A, and is supplied pre-aligned and ready for use without adjustment.

Typical test results for a setup using a 75A, RG-58/U coaxial leads, and type CS-____ Capacitance Standards are given in Table 2.

TABLE 2

CS-___ Three-Terminal Capacitance Standard	Nameplate Value (pf)	75A CAPACITANCE READINGS USING RG-58/U COAXIAL CABLES					
		Cable Length 3-1/2 inches			Cable Length 9-1/2 inches		
		@ 100Kc	@ 465 Kc	@ 1 Mc	@ 100Kc	@ 465Kc	@ 1 Mc
CS-1000	1000.4	1000.1	1001.0	1003.9	1000.1	1001.7	1007.4
CS-750	743.9	743.8	744.05	745.4	743.8	744.6	747.4
CS-500	499.7	499.8	499.8	500.05	499.8	500.05	501.0
CS-300	299.7	299.85	299.8	299.6	299.85	299.9	300.0
CS-100	100.00	99.75	99.64	99.45	99.75	99.64	99.51

The Comparative data in Table 2 for measurements made using 3-1/2 inch and 9-1/2 inch RG-58/U coaxial leads shows that a 1 Mc it is impossible to measure a 1000 pf standard without incurring lead inductance errors. Each inch of increase in the length of the cables is shown to cause a 0.6 pf (0.06%) increase in the reading.

Table 3 interprets the data in Table 2 in terms of the increase in capacitance reading per inch and per foot of cable extensions. (See also Graph 1 of APPENDIX A)

TABLE 3

INCREASE IN CAPACITANCE READING DUE TO INDUCTANCE OF RG-58/U COAXIAL CABLES.					
Value of Capacitance Standard	At 1 Mc		At 465 Kc		At 100 Kc
	Per ft. of cable	Per inch of cable	Per ft. of cable	Per inch of cable	
1000 pf	7 pf	0.58 pf	1.4 pf	0.12 pf	(Negligible error - no correction required)
750 pf	4 pf	0.33 pf	1.1 pf	0.09 pf	
500 pf	1.9 pf	0.16 pf	0.5 pf	0.04 pf	
300 pf	0.8 pf	0.066 pf	0.2 pf	0.017 pf	
100 pf	0.1 pf	-	-	-	
(Subtract to Correct)					

TO SUMMARIZE:

1. The effects of lead inductance inside the 75A are small enough that at 1 Mc specified accuracy is met without using corrections - provided the capacitor to be measured is connected directly at the HI and LO TEST binding posts or TEST coaxial receptacles. If greater accuracy is required, apply the corrections given in Table 1 to correct for internal inductance effects.

2. The capacitance accuracy on the X1 range of the 75A should preferably be checked at 100 Kc.

3. For capacitance measurements at 1 Mc above 100 pf, correction must be made for the effects of the coaxial leads used between the test and the bridge, and may be figured from Table 3.

AN EXAMPLE:

A 75A is to have its capacitance accuracy checked on the X1 Capacitance range at 1 Mc, using 100, 500 and 1000 pf type CS-___ Capacitance Standards connected to the bridge with 6 inch RG-58/U coaxial cables.

If no 100 Kc Oscillator/Detector unit is available, a fairly accurate check can still be made by measuring the Standards at 1 Mc, and applying both the corrections from Table 1 and Table 3 of this paper. The corrected readings should fall well within the bridge guarantee specifications.

(1)	Standard: CS-___	"100"	"500"	"1000"
(2)	Certified (Nameplate) Value of Standard	100.01 pf	500.26 pf	1000.4 pf
(3)	Reading on 75A with 6" RG-58/U Coax. leads	99.8 pf	500.7 pf	1005.4 pf
(4)	Correction from Table 1	+0.28 pf	+0.41 pf	-1.2 pf
(5)	Correction from Table 3	-0.05 pf	-0.95 pf	-3.5 pf
(6)	Net correction (4) + (5)	+0.23 pf	-0.54 pf	-4.7 pf
(7)	Corrected reading (3) + (6)	100.03 pf	500.16 pf	1000.7 pf
(8)	Bridge Calibr. Error (7) vs. (2)	+0.02 pf	-0.1 pf	+0.3 pf
(9)	Guarantee Tolerance ± (0.25% + 0.5 pf) on X1 Range	±0.75 pf	±1.75 pf	±3.0 pf

APPENDIX C

THE MEASUREMENT OF "LOSSY" CAPACITORS

To accurately measure the capacitance of "lossy" capacitors (those with equivalent parallel resistance in the general region between 1000 Ω and 1 megohm) it is necessary to construct and use a set of correction curves for each individual bridge.

To do this, acquire a set of deposited carbon resistors (Mepco 1/4 W Type C10 is recommended) with values ranging between 1000 Ω and 1 megohm. Measure* each of the resistors on the bridge and plot the capacitance readings, preferably on semi-log graph paper. Use their true capacitance (0.07 pf for Mepco 1/4 W Type C10) as the zero reference for determining the magnitude and direction of the bridge error.

Typical data is shown in the following table:

(For illustration only - do not use unless verified)

	Resistor (Ω)	Bridge Reading (1)	True Value (2)	Indicated Correction (1) - (2) with sign inverted
X1 DIVIDE G/ MULTIPLY R range	1 K	-0.33 pf	+0.07 pf	+0.40 pf
	1.2 K	0.00	"	+0.07
	1.5 K	+0.11	"	-0.04
	2 K	+0.26	"	-0.19
	3 K	+0.22	"	-0.15
	5 K	+0.20	"	-0.13
	10 K	+0.10	"	-0.03
X10 DIVIDE G/ MULTIPLY R range	10 K	+0.35 pf	+0.07 pf	-0.28 pf
	12 K	+0.39	"	-0.32
	15 K	+0.35	"	-0.28
	20 K	+0.30	"	-0.23
	30 K	+0.22	"	-0.15
	50 K	+0.14	"	-0.07
	100 K	+0.10	"	-0.03
X100 DIVIDE G/ MULTIPLY R range	100 K	+0.088 pf	+0.07 pf	-0.018 pf
	120 K	+0.091	"	-0.021
	150 K	+0.085	"	-0.015
	200 K	+0.078	"	-0.008
	300 K	+0.068	"	+0.002
	500 K	+0.064	"	+0.006
	1 Meg	+0.07	"	0.00

Note that the capacitance error does not depend on the capacitance value of the test, but on its resistive component. Hence for any given value of equivalent resistance it is what might be called a "fixed pf" error, the effect on the test varying in percentage with the size of the test capacitance.

For example, if the test consisted of a capacitor with equivalent parallel resistance of 5000 Ω and a true capacitance of .5 pf (such as might be found in semiconductor work) the measured C would be about .63 pf. If not corrected this would represent an error of about 25% from true. If the true capacitance had been 5 pf, however, the error would have been only about 2.5%.

* Connect by pushing their leads (cut to approximately 3/4 inch long on each end) into the centers of the HI and LO coaxial TEST receptacles of the bridge.

SECTION 11

TABLE OF REPLACEABLE PARTS

NOTE:
Components in the "Bridge" unit have not been included, since in general their replacement must be followed by adjustments that require specialized equipment and techniques.

CAPACITORS

Reference	Description			BEC Part No.
C1	Sil. Mica	75 pf ±5%	Arco CM15F750J	200,013
C2	Ceramic	20 pf ±2% Zero T.C.	CRL TCZ-20	220,114
C3	Ceramic, Var.	4.5-25 pf " "	Erie 503-041 37R	281,000
C4	Electrolytic	8 µf/350 v.	Sprague TVA 1603	283,126
C5	Mylar	0.01 µf ±20% 400 v.		234,021
C6	Ceramic, Var.	4.5-25 pf Zero T.C.	Erie 503-041 37R	281,000
C7	Mylar	0.022 µf ±20% 200 v.		230,101
C8	Mylar	0.01 µf ±20% 400 v.		234,021
C9	Mylar	0.01 µf ±20% 400 v.		234,021
C10	Sil. Mica	750 pf ±2%	Arco DM19F751G	200,502
C11	Mylar	0.01 µf ±20% 400 v.		234,021
C12	Met. Paper	0.25 µf $^{-20}_{+30}$% 400 v.	Astron MLL-4-25	230,105
C13	Electrolytic	50 µf/25 v.	Industrial Cond. 52RMV50	283,110
C14	Mylar	0.1 µf ±20% 200 v.		230,116
C15	Met. Paper	1 µf ±20% 200 v.		230,104
C16	Electrolytic	8 µf/350 v.	Sprague TVA 1603	283,126

Reference		Description		BEC Part No.
C17	Mylar	0.1 μf ±20% 200 v.		230,116
C18	Ceramic, Var.	4.5-25 pf Zero T.C.	Erie 503-041 37R	281,000
C19	Sil. Mica	10 pf ±5%	Arco DM10C100J	200,022
C20	" "	39 pf ±5%	Arco DM15E390J	200,025
C21	Ceramic, Var.	4.5-25 pf Zero T.C.	Erie 503-041 37R	281,000
C22	Sil. Mica	560 pf ±2%	Arco DM19F561G	200,504
C23	Ceramic, Var.	7-45 pf N500 PPM	Erie 503-041 33R	275,114
C24	Ceramic, Var.	3-12 pf Zero T.C.	Erie 503-041 17R	275,113
C25	Sil. Mica	680 pf ±1%	Arco DM19F681F	200,503
C26	Mylar	0.01 μf ±20% 200 v.		230,120
C27	"	0.005 μf ±20% 200 v.		230,121
C28	Mylar	0.1 μf ±20% 400 v.		230,116
C29	Electrolytic	10 μf/6 v.		283,130
C30	Mylar	0.1 μf ±20% 400 v.		230,116
C31 thru C34 (not used)				
C35 thru C46 (in "Bridge" unit)				
C47 thru C51 (not used)				
C52	Electrolytic	10, 30, 10 μf 450 v.	Mallory FP376.6	283,141
C53	Sil. Mica	0.001 μf ±5%	Arco CM20E102J	201,143
C54	Mylar	0.1 μf ±20% 400 v.		230,124

Reference		Description		BEC Part No.
C55	Sil. Mica	0.001 μf ±5%	Arco CM20E102J	201,143
C56	" "	0.001 μf ±5%	" " "	"
C57	Mylar	0.1 μf ±20% 200 v.		230,116
C58	Mylar	0.1 μf ±20% 200 v.		230,116
C59	Electrolytic	50 μf/6 v.		283,112
C60	Mylar	0.1 μf ±20% 400 v.		230,124
C61	Electrolytic	10 μf/6 v.	Sprague TE-1087	283,130
C62	Mylar	0.1 μf ±20% 400 v.		230,124
C63	Met. Paper	1 μf ±20% 200 v.		230,104
C64	Mylar	0.1 μf ±20% 200 v.		230,116

RESISTORS

All Composition Resistors are Allen-Bradley Type EB, GB or HB

R1	Comp., Var.	Dual 500 K ±10% 2W Log	AB Type J	311,140
R2	Comp.	3.9 K ±5% 1/2W		301,101
R3	"	"		"
R4	"	470 K ±5% 1/2W		301,151
R5	"	8.2 K ±10% 1/2W		301,209
R6	"	330 Ω ±5% 1/2W		301,075
R7	"	2.2 M ±10% 1/2W		301,033
R8	Comp., Var.	5 K ±10% 2W Linear	AB Type J	311,134

Reference	Description		BEC Part No.
R9	Comp., Var.	5 K ±10% 1/10W Linear CRL BA-001	311,169
R10	Comp.	15 K ±5% 1W	302,129
R11	"	330 Ω ±5% 1/2W	301,075
R12	"	100 K ±10% 1/2W	301,025
R13	"	1.6 K ±5% 1/2W	301,092
R14	"	15 K ±5% 1W	302,129
R15	"	5.6 K ±5% 2W	304,105
R16	"	150 K ±5% 1/2W	301,139
R17	"	220 K ±10% 1/2W	301,027
R18	Wirewound, Non-inductive	6 K ±3% 5W Dale Type NS-5	309,018
R19	Comp.	620 Ω ±5% 1/2W	301,082
R20	"	1 K ±5% 1/2W	301,087
R21	"	220 K ±10% 1/2W	301,027
R22	"	470 Ω ±5% 1/2W	301,079
R23	Comp.	47 K ±5% 1/2W	301,127
R24	"	470 K ±5% 1/2W	301,151
R25	Comp., Var.	50 K ±10% 2W Linear AB Type J	311,125
R26	Comp.	100 K ±10% 1/2W	301,025
R27	Comp., Var.	5 K ±10% 1/10W Linear CRL BA-001	311,169
R28	"	" " " " " "	"

Reference		Description		BEC Part No.
R29	Comp., Var.	5K ±10% 1/10W Linear	CRL BA-001	311,169
R30	Comp.	2.7 K ±5% 1/2W		301,097
R31	Wirewound, Var.	Dual 50 K Linear (SPECIAL)		311,166
R32	Dep. Carbon	8.25 K ±1% 1/2W	Texas CD 1/2 PR	306,350
R33	Comp.	15 K ±5% 1/2W		301,043
R34	Dep. Carbon	16.5 K ±1% 1/2W	Texas CD 1/2 PR	306,385
R35	Comp.	1 M ±5% 1/2 W		301,159
R36	"	150 K ± 10% 1/2W		301,008
R37	Comp.	15 K ±5% 1W		302,129
R38	"	22 K ±10% 1/2W		301,021
R39 thru R43 (not used)				
R44 thru R59 (in "Bridge" unit)				
R60	Comp.	47 K ±10% 1/2W		301,023
R61	Comp., Var.	50 K ±10% 2W Log	AB Type J	311,129
R62	Comp.	15 K ±5% 2W		304,115
R63 thru R66 (not used)				
R67	Comp.	150 Ω ±10% 1W		302,008
R68	"	"		"
R69	"	1 M ±20% 1W		302,128
R70	Wirewound	8.5 K ±5% 10W		312,110
R71	Comp.	68 K ±10% 1W		302,024

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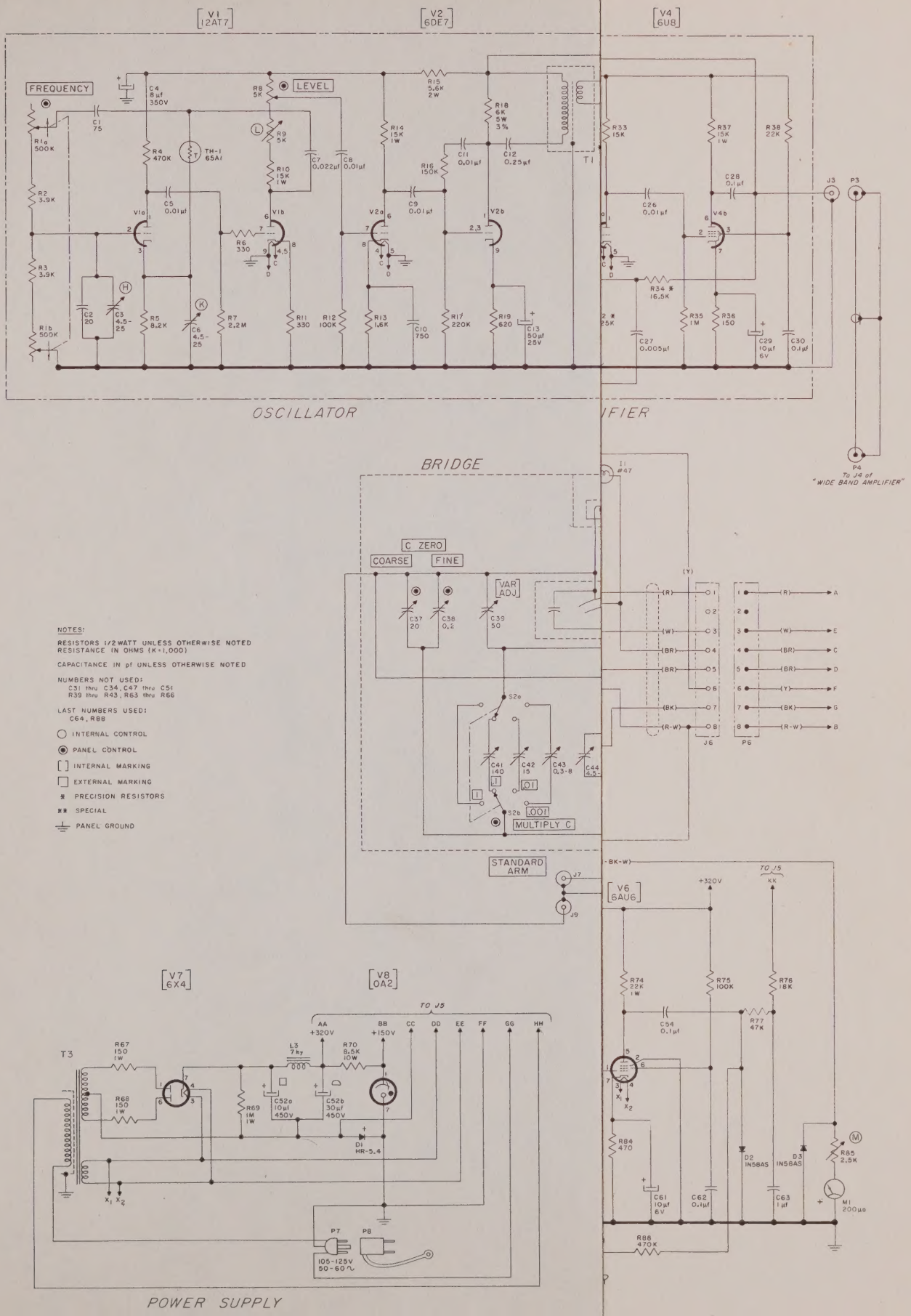
Reference		Description		BEC Part No.
R72	Comp.	18 K ±5% 1/2W		301,117
R73	Comp.	47 K ±5% 1/2W		301,127
R74	Comp.	22 K ±5% 1W		302,133
R75	Comp.	100 K ±10% 1/2W		301,025
R76	Comp.	18 K ± 5% 1/2W		301,117
R77	Comp.	47 K ±5% 1/2W		301,127
R78	Comp.	470 K ±10% 1/2W		301,151
R79	Comp.	"		"
R80	Comp.	"		"
R81	Comp.	"		"
R82	Comp.	330 Ω ±5% 1/2W		301,075
R83	Comp.	1 M ±5% 1/2W		301,159
R84	Comp.	470 Ω ±5% 1/2W		301,079
R85	Comp., Var.	2.5 K ±10% 1/10W	CRL BA-001	311,128
R86	Comp.	2.2 M ±10% 1/2W		301,033
R87	Comp.	470 K ±5% 1/2W		301,151
R88	Comp.	"		"
D1	Diode, Zener	5.4V ±5% 1/2W		530,020
D2	Diode, R.F.	1N58A (100 v PRV)	Sylvania 1N58AS	530,021
D3	Diode, R.F.	1N58A (100 v PRV)	Sylvania 1N58AS	530,021

Reference	Description			BEC Part No.
F1	Fuse	1A	Buss AGC-1	545,500
I1	Bulb	#47		545,101
L1	Choke, R.F.	2.5 mh	Miller 6302	400,014
L2	Choke, A.F.	(in bridge unit)		
L3	Choke, Power	7 hy. 500 Ω 50 ma.	Stancor C1707	440,001
L4	" , R.F.	2.5 mh	Miller 6302	400,014
M1	Meter	200 μa 475 Ω Special Scale		554,116
S1	Switch, Rotary		CRL PS-113	466,128
S2	Switch, Rotary	(in bridge unit)		
S3	Switch, Rotary	(in bridge unit)		
S4	Switch, Rotary	SP3T	CRL 1461	466,119
S5	Switch, Toggle	SPST	Carling 110-63	465,105
T1	Transformer, Osc. Output			075,180
T2	Transformer, Bridge Input	(in bridge unit)		
T3	Transformer, Power			446,020

Reference	Description			BEC Part No.
TH1	Thermistor		Veco 65A1	325,001
V1	Tube	12AT7		526,12AT7
V2	Tube	6DE7		526,6DE7
V3	Tube	6AK5		526,6AK5
V4	Tube	6U8		526,6U8
V5	Tube	6AU6		526,6AU6
V6	Tube	6AU6		"
V7	Tube	6X4		526,6X4
V8	Tube	0A2		526,0A2


V1 12AT7
V2 6DE7
V4 6U8
FREQUENCY
LEVEL
OSCILLATOR
BRIDGE
C ZERO
COARSE
FINE
VAR ADJ
MULTIPLY C
STANDARD ARM
NOTES:
RESISTORS 1/2 WATT UNLESS OTHERWISE NOTED
RESISTANCE IN OHMS (K=1,000)
CAPACITANCE IN pf UNLESS OTHERWISE NOTED
NUMBERS NOT USED:
C31 thru C34, C47 thru C51
R39 thru R43, R63 thru R66
LAST NUMBERS USED:
C64, R88
INTERNAL CONTROL
PANEL CONTROL
INTERNAL MARKING
EXTERNAL MARKING
PRECISION RESISTORS
SPECIAL
PANEL GROUND
V7 6X4
V8 0A2
V6 6AU6
T3
TO J5
TO J5
105-125V 50-60~
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